US009348254B2

(12) **United States Patent**
Mitsunobu

(10) **Patent No.: US 9,348,254 B2**
(45) **Date of Patent: May 24, 2016**

(54) **IMAGE FORMING APPARATUS**

(75) Inventor: **Hidetaka Mitsunobu**, Tokyo (JP)

(73) Assignee: **Oki Data Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 936 days.

(21) Appl. No.: **13/357,649**

(22) Filed: **Jan. 25, 2012**

(65) **Prior Publication Data**

US 2012/0189355 A1 Jul. 26, 2012

(30) **Foreign Application Priority Data**

Jan. 26, 2011 (JP) 2011-013703

(51) **Int. Cl.**
G03G 15/08 (2006.01)
G03G 15/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G03G 15/0808*** (2013.01); ***G03G 15/0887*** (2013.01); ***G03G 15/0889*** (2013.01); ***G03G 15/505*** (2013.01); ***G03G 15/5058*** (2013.01)

(58) **Field of Classification Search**
CPC G03G 15/0887; G03G 15/0889; G03G 15/0891; G03G 15/0865; G03G 15/0877
USPC 399/258, 263, 281
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,404,211 A * 4/1995 Hashimoto et al. 399/126
5,809,386 A * 9/1998 Iwata 399/281
5,812,917 A * 9/1998 Iwata et al. 399/281
5,832,350 A * 11/1998 Kumasaka et al. 399/282
6,353,720 B1 * 3/2002 Sakai et al. 399/234

FOREIGN PATENT DOCUMENTS

JP H04-127177 A 4/1992
JP H06-175487 A 6/1994
JP 09171286 A * 6/1997 .... G03G 15/06
JP H09-236979 A 9/1997
JP 10-039628 A 2/1998
JP 2001-175066 A 6/2001

* cited by examiner

Primary Examiner — David Gray
Assistant Examiner — Andrew V Do
(74) *Attorney, Agent, or Firm* — Panitch Schwarze Belisario & Nadel LLP

(57) **ABSTRACT**

An image forming apparatus includes a developer bearing body and first and second supplying members. An image bearing body and the first and second supplying members are disposed around the developer bearing body in this order. The developer bearing member rotates, and supplies a developer material to the image bearing body. The first and second supplying members rotate in contact with the developer bearing body and supply the developer material to the developer bearing body. The image bearing body is upstream of the second supplying member with respect to rotation of the developer bearing body, and the second supplying member is upstream of the first supplying member. The ratio of the circumferential speed of the first supplying member to that of the developer bearing body is larger than that of the circumferential speed of the second supplying member to circumferential speed of the developer bearing body.

15 Claims, 12 Drawing Sheets

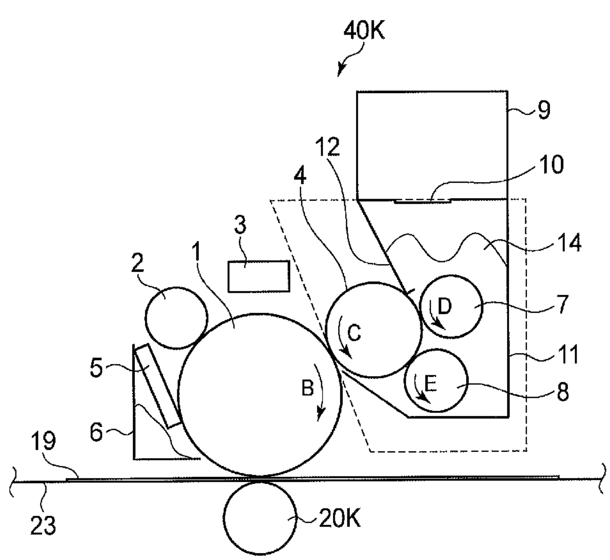

FIG.1

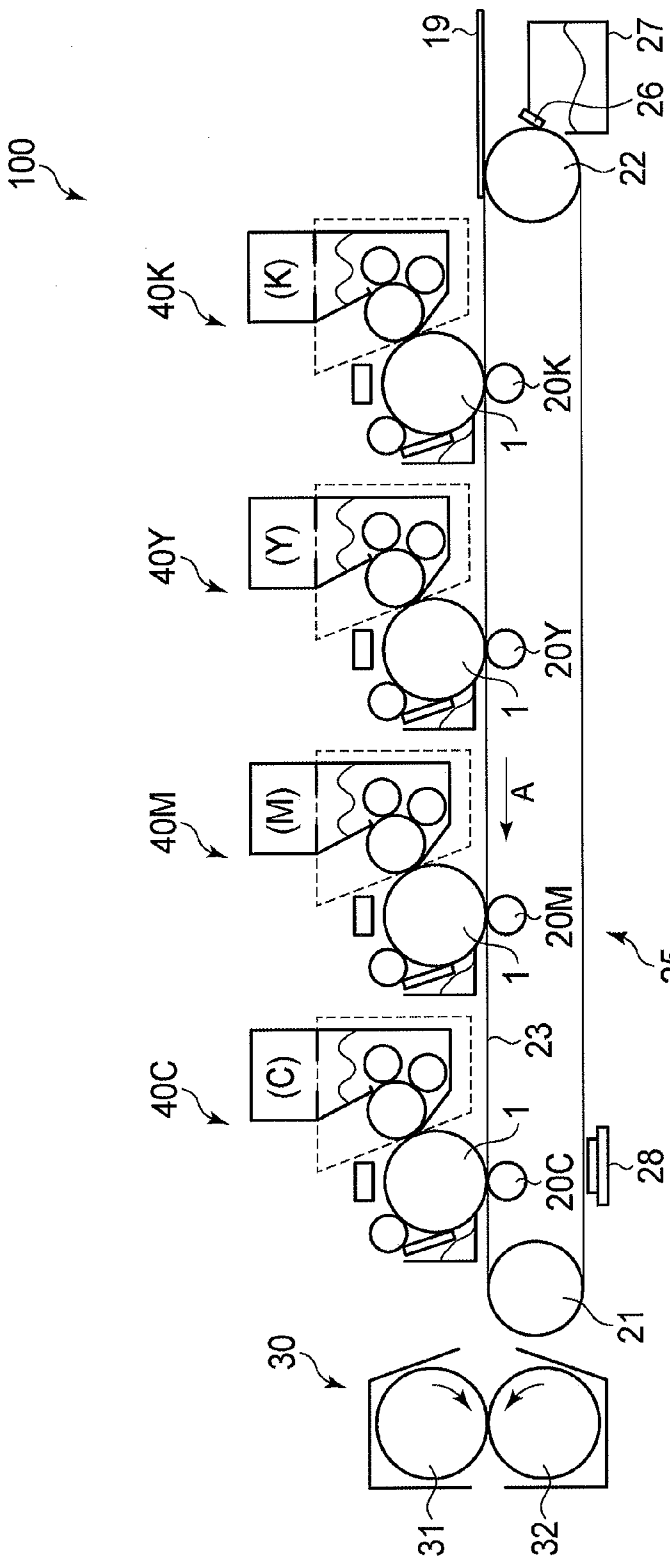
100
19
27
26
22
40K
(K)
20K
1
40Y
(Y)
20Y
40M
(M)
A
20M
25
40C
(C)
23
20C
28
21
30
31
32

FIG.2

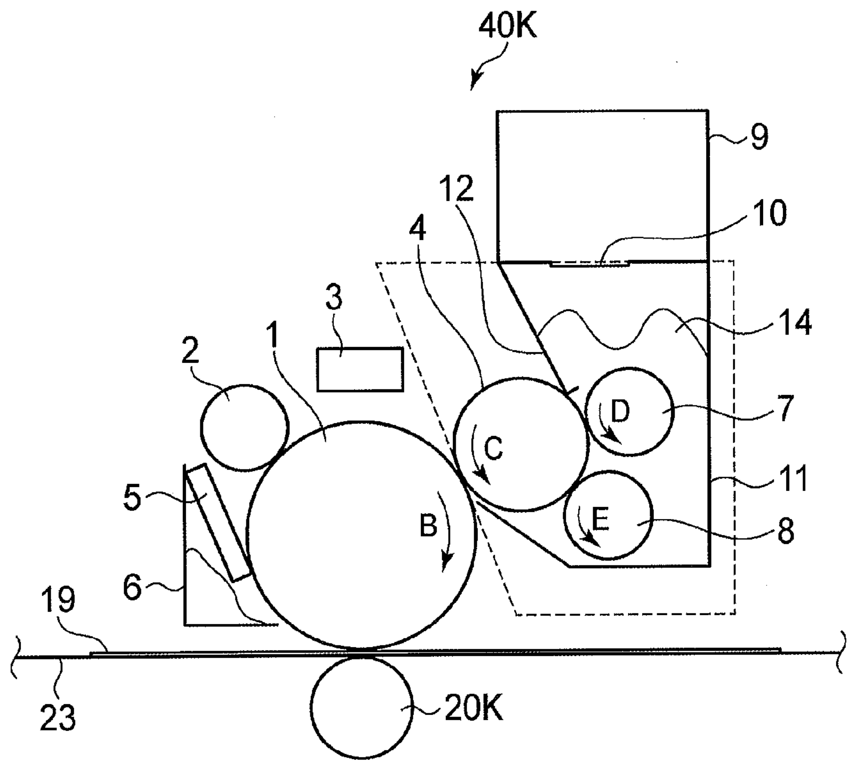
40K
9
12
10
4
14
3
2
1
7
D
C
11
5
B
E
8
6
19
23
20K

FIG.3

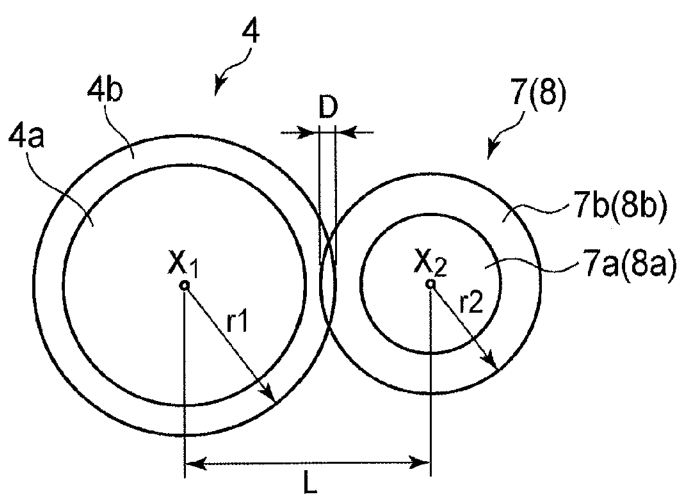
4
4b
D
7(8)
4a
7b(8b)
X_1
X_2
7a(8a)
r1
r2
L

FIG.4

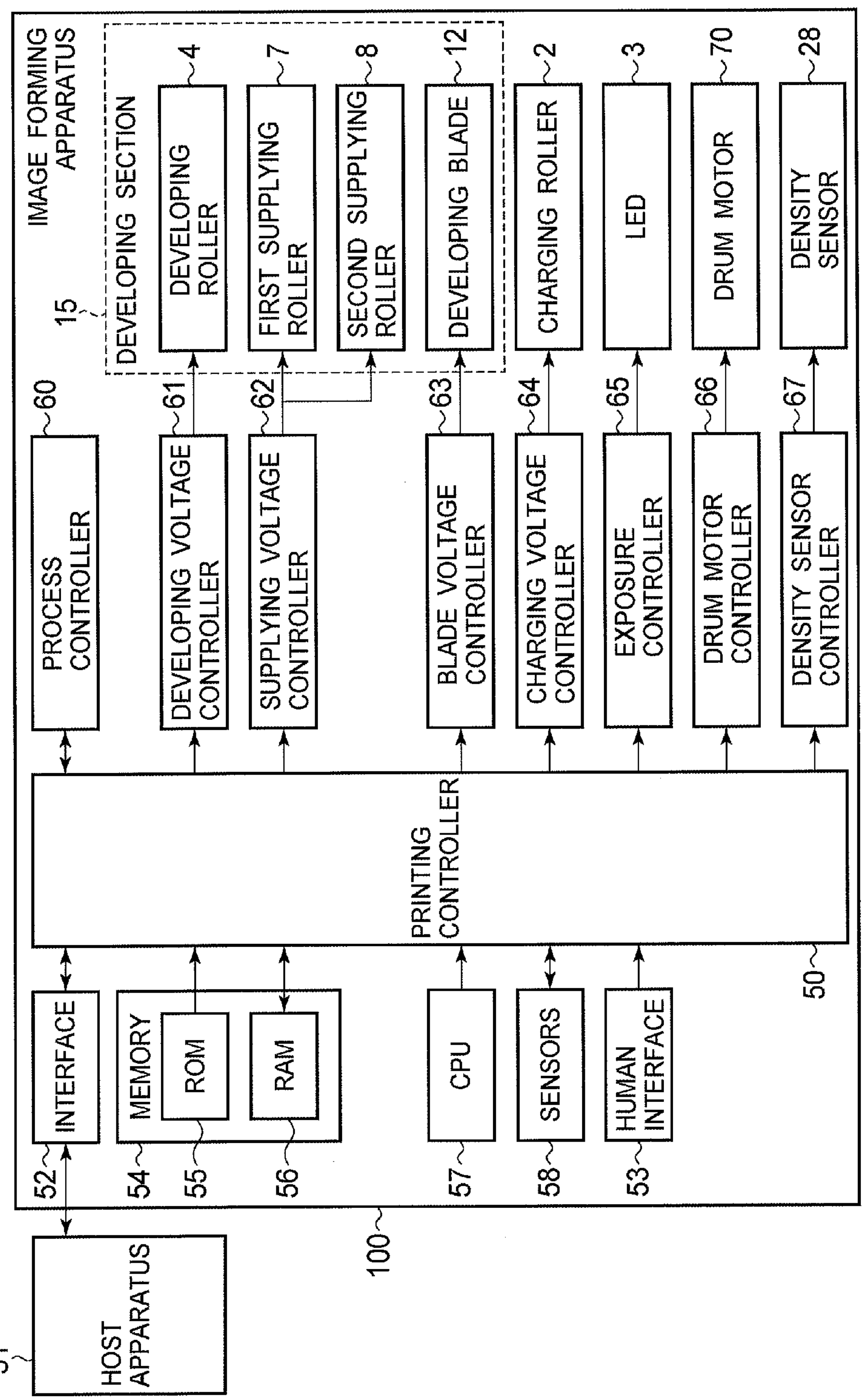
IMAGE FORMING APPARATUS
100
DEVELOPING SECTION
15
DEVELOPING ROLLER
4
FIRST SUPPLYING ROLLER
7
SECOND SUPPLYING ROLLER
8
DEVELOPING BLADE
12
CHARGING ROLLER
2
LED
3
DRUM MOTOR
70
DENSITY SENSOR
28
PROCESS CONTROLLER
60
DEVELOPING VOLTAGE CONTROLLER
61
SUPPLYING VOLTAGE CONTROLLER
62
BLADE VOLTAGE CONTROLLER
63
CHARGING VOLTAGE CONTROLLER
64
EXPOSURE CONTROLLER
65
DRUM MOTOR CONTROLLER
66
DENSITY SENSOR CONTROLLER
67
PRINTING CONTROLLER
50
INTERFACE
52
MEMORY
54
ROM
55
RAM
56
CPU
57
SENSORS
58
HUMAN INTERFACE
53
HOST APPARATUS
51

FIG.5

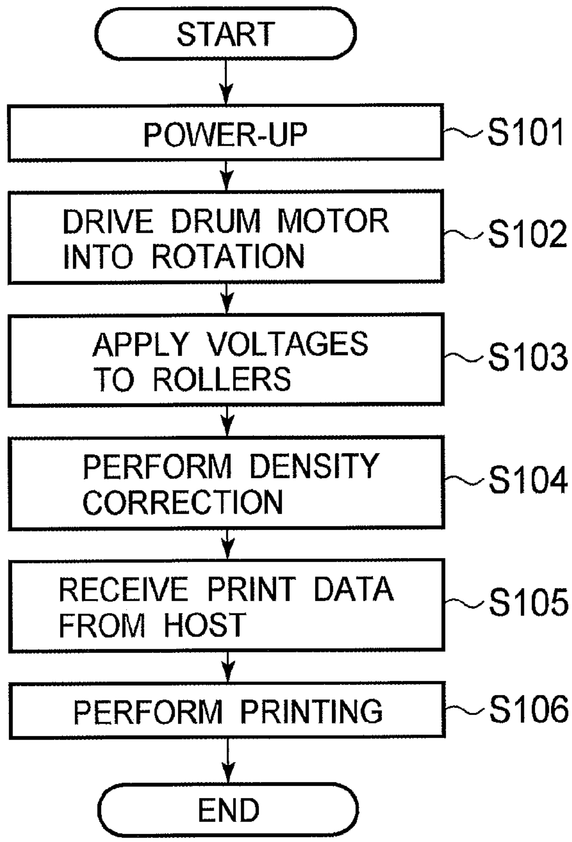
START
POWER-UP
S101
DRIVE DRUM MOTOR INTO ROTATION
S102
APPLY VOLTAGES TO ROLLERS
S103
PERFORM DENSITY CORRECTION
S104
RECEIVE PRINT DATA FROM HOST
S105
PERFORM PRINTING
S106
END

FIG.6

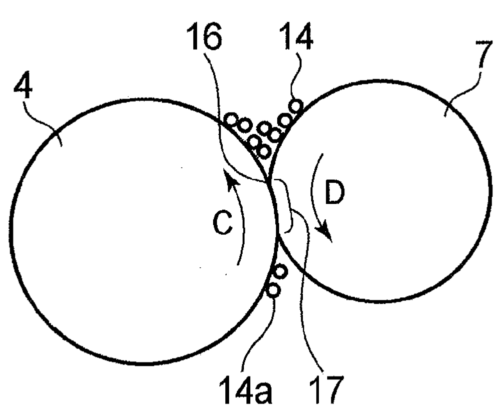
16
14
7
4
C
D
14a
17

FIG.7

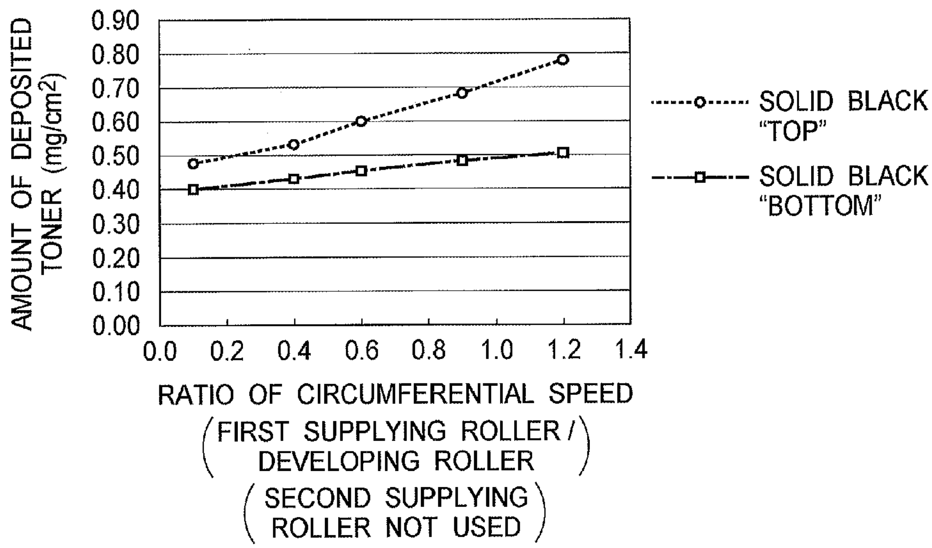
AMOUNT OF DEPOSITED TONER (mg/cm2)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
RATIO OF CIRCUMFERENTIAL SPEED
(FIRST SUPPLYING ROLLER / DEVELOPING ROLLER)
(SECOND SUPPLYING ROLLER NOT USED)
SOLID BLACK "TOP"
SOLID BLACK "BOTTOM"

FIG.8

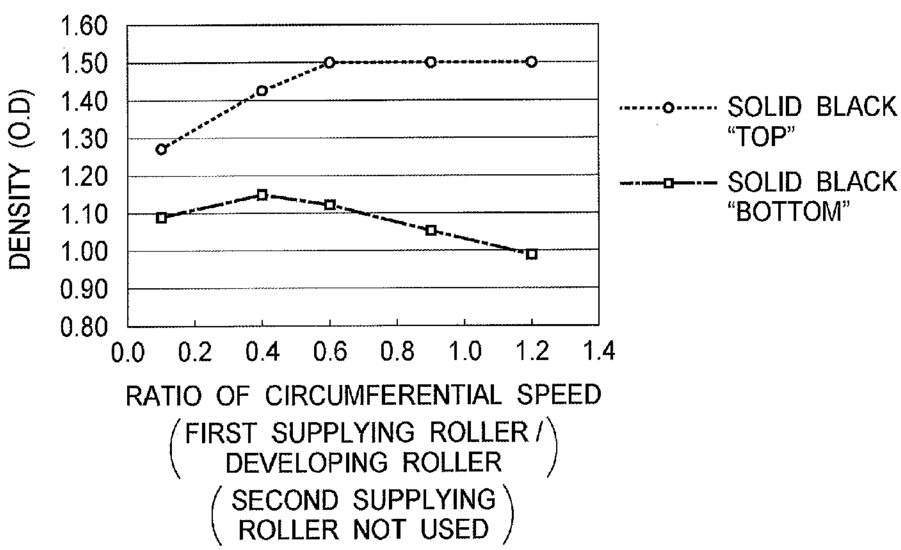
DENSITY (O.D)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
RATIO OF CIRCUMFERENTIAL SPEED
(FIRST SUPPLYING ROLLER / DEVELOPING ROLLER)
(SECOND SUPPLYING ROLLER NOT USED)
SOLID BLACK "TOP"
SOLID BLACK "BOTTOM"

FIG.9A

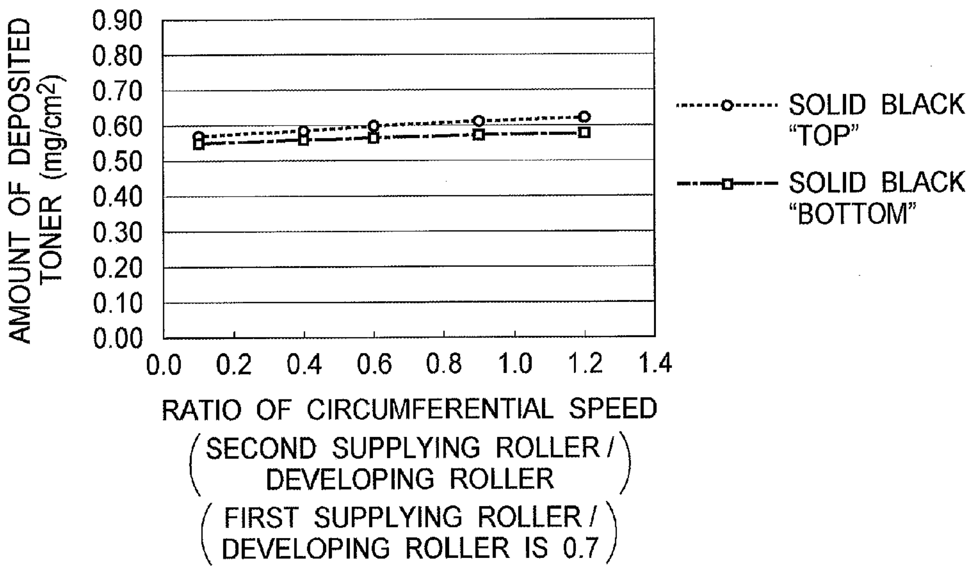
AMOUNT OF DEPOSITED TONER (mg/cm2)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
SOLID BLACK "TOP"
SOLID BLACK "BOTTOM"
RATIO OF CIRCUMFERENTIAL SPEED
(SECOND SUPPLYING ROLLER / DEVELOPING ROLLER)
(FIRST SUPPLYING ROLLER / DEVELOPING ROLLER IS 0.7)

FIG.9B

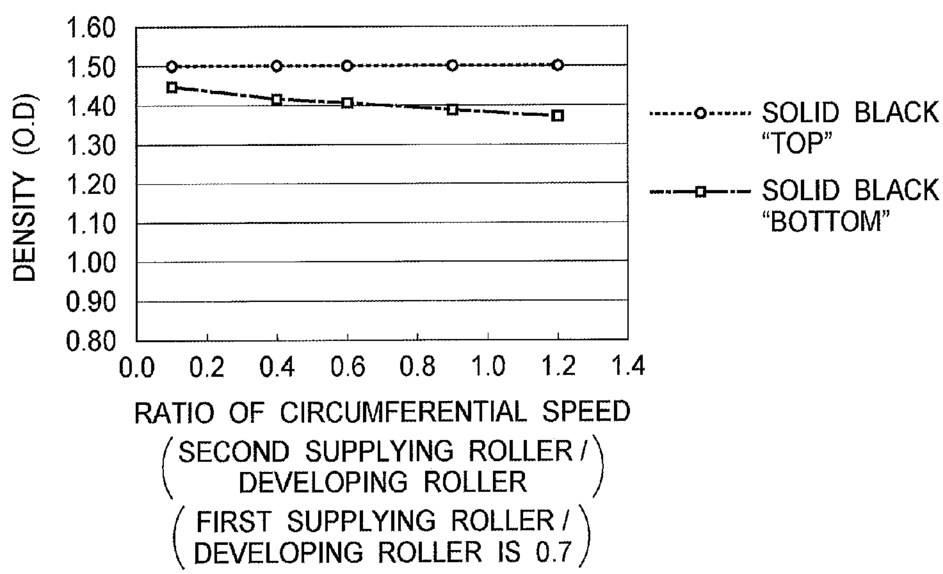
DENSITY (O.D)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
SOLID BLACK "TOP"
SOLID BLACK "BOTTOM"
RATIO OF CIRCUMFERENTIAL SPEED
(SECOND SUPPLYING ROLLER / DEVELOPING ROLLER)
(FIRST SUPPLYING ROLLER / DEVELOPING ROLLER IS 0.7)

FIG.10A

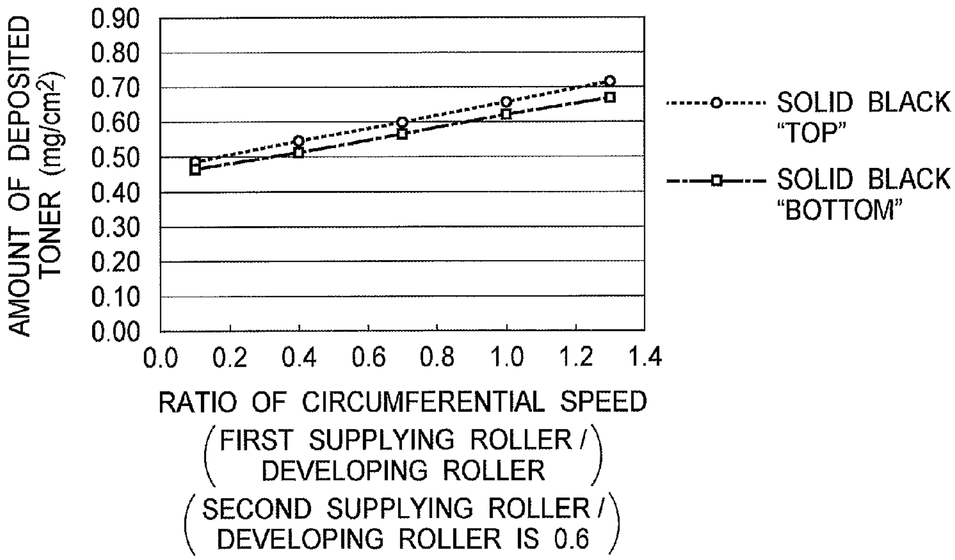

FIG.10B

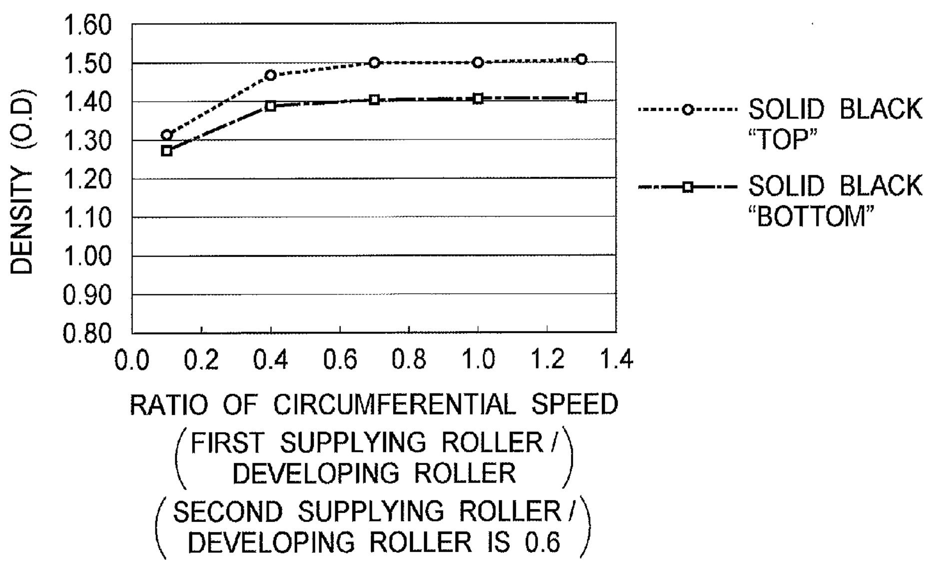

FIG.11

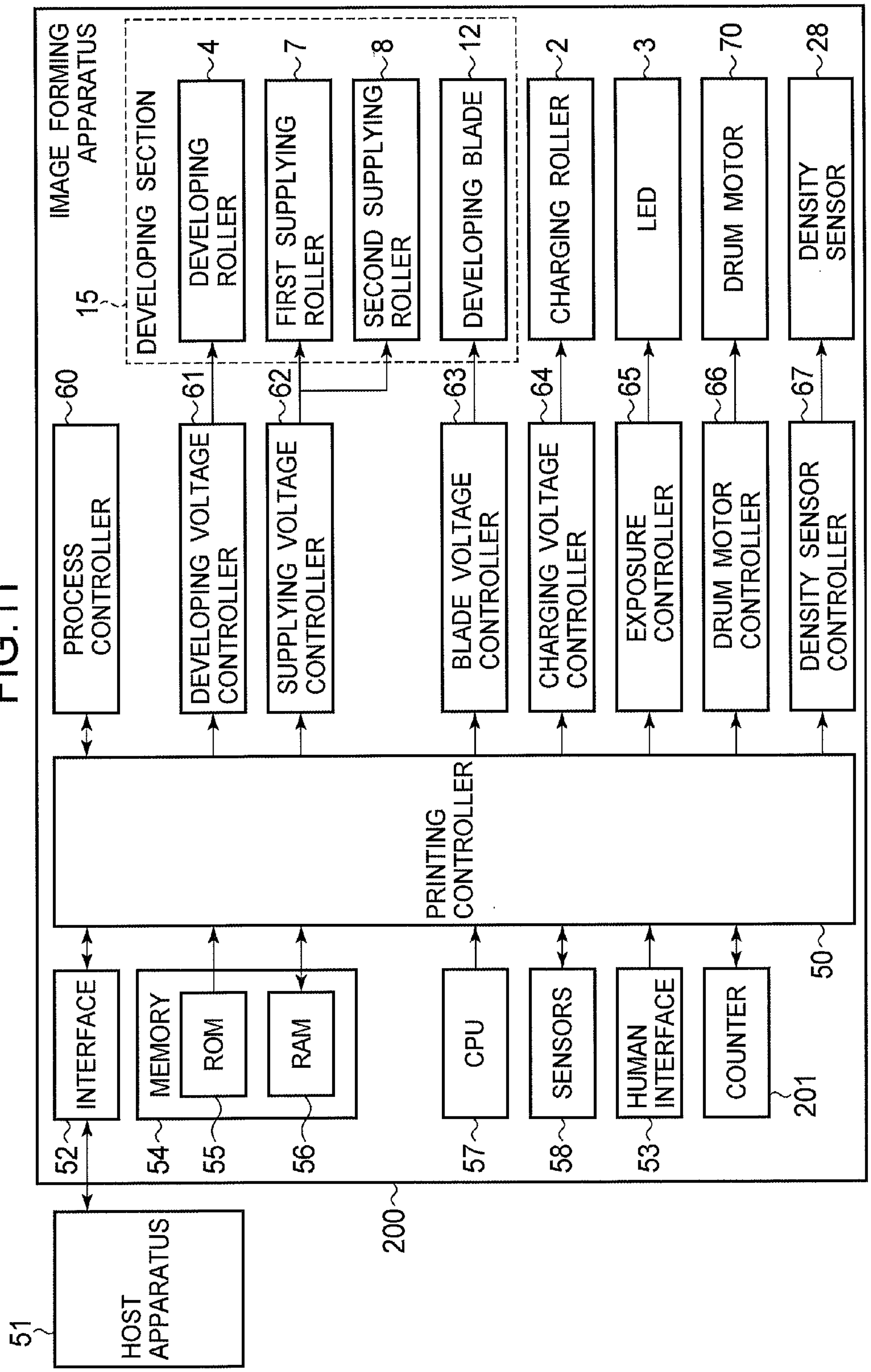
IMAGE FORMING APPARATUS
200
HOST APPARATUS
51
INTERFACE
52
MEMORY
54
ROM
55
RAM
56
CPU
57
SENSORS
58
HUMAN INTERFACE
53
COUNTER
201
PRINTING CONTROLLER
50
PROCESS CONTROLLER
60
DEVELOPING VOLTAGE CONTROLLER
61
SUPPLYING VOLTAGE CONTROLLER
62
BLADE VOLTAGE CONTROLLER
63
CHARGING VOLTAGE CONTROLLER
64
EXPOSURE CONTROLLER
65
DRUM MOTOR CONTROLLER
66
DENSITY SENSOR CONTROLLER
67
DEVELOPING SECTION
15
DEVELOPING ROLLER
4
FIRST SUPPLYING ROLLER
7
SECOND SUPPLYING ROLLER
8
DEVELOPING BLADE
12
CHARGING ROLLER
2
LED
3
DRUM MOTOR
70
DENSITY SENSOR
28

FIG.12

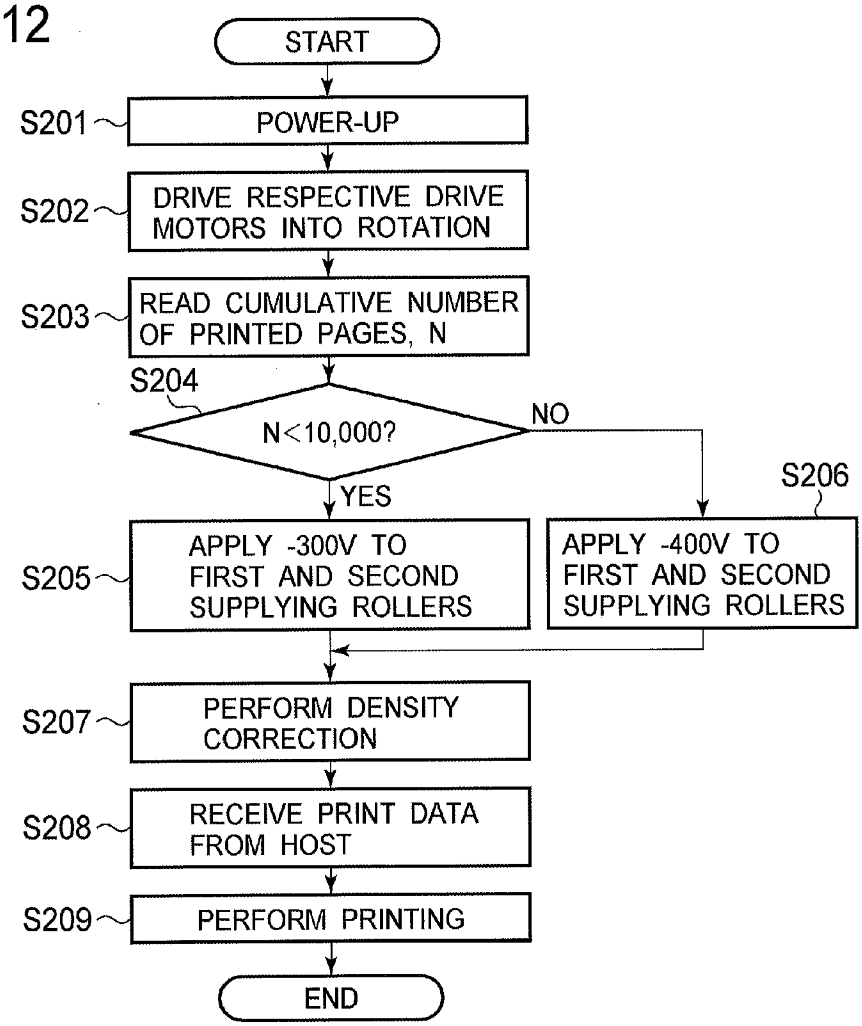
START
S201
POWER-UP
S202
DRIVE RESPECTIVE DRIVE MOTORS INTO ROTATION
S203
READ CUMULATIVE NUMBER OF PRINTED PAGES, N
S204
N<10,000?
NO
YES
S205
APPLY -300V TO FIRST AND SECOND SUPPLYING ROLLERS
S206
APPLY -400V TO FIRST AND SECOND SUPPLYING ROLLERS
S207
PERFORM DENSITY CORRECTION
S208
RECEIVE PRINT DATA FROM HOST
S209
PERFORM PRINTING
END

FIG.13

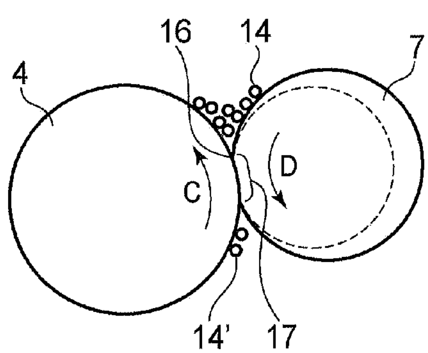
16
14
7
4
C
D
14'
17

FIG.14

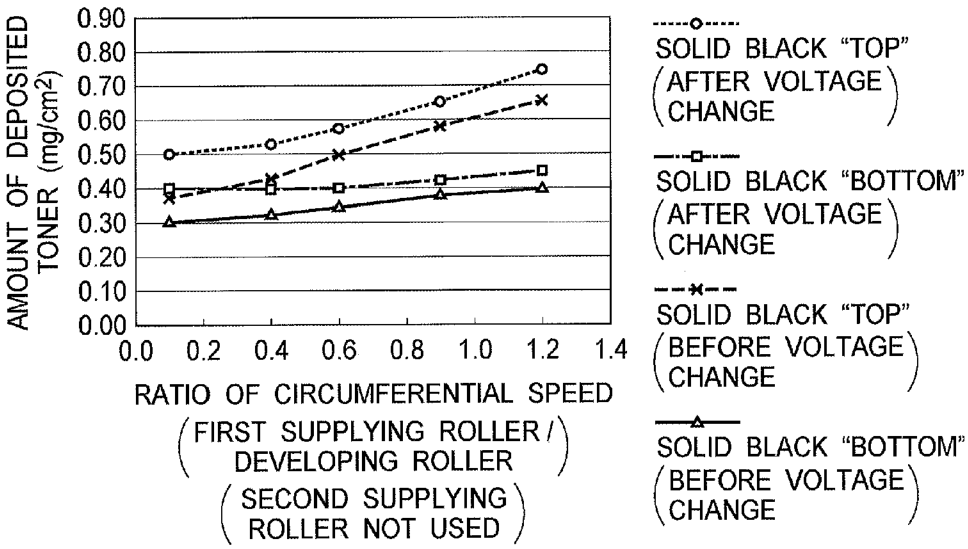
AMOUNT OF DEPOSITED TONER (mg/cm2)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
RATIO OF CIRCUMFERENTIAL SPEED
(FIRST SUPPLYING ROLLER / DEVELOPING ROLLER)
(SECOND SUPPLYING ROLLER NOT USED)
SOLID BLACK "TOP" (AFTER VOLTAGE CHANGE)
SOLID BLACK "BOTTOM" (AFTER VOLTAGE CHANGE)
SOLID BLACK "TOP" (BEFORE VOLTAGE CHANGE)
SOLID BLACK "BOTTOM" (BEFORE VOLTAGE CHANGE)

FIG.15

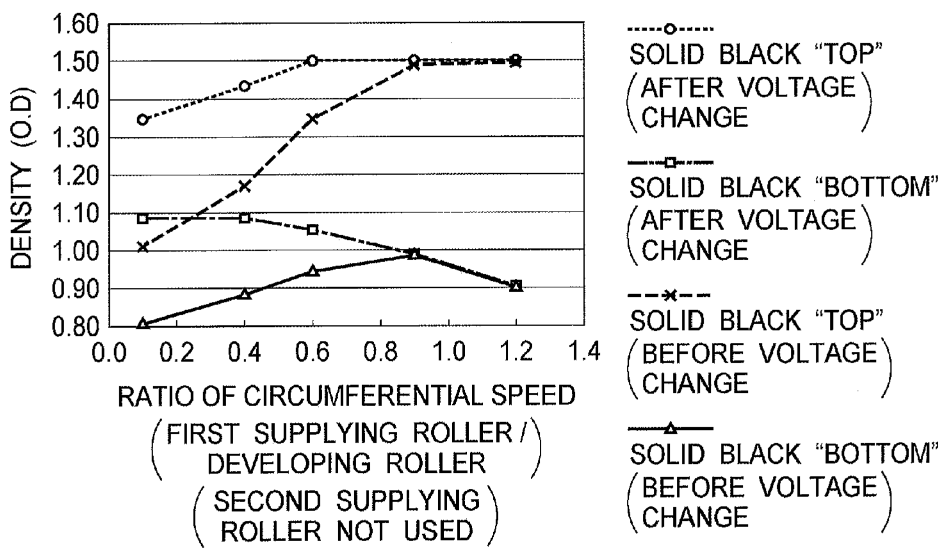
DENSITY (O.D)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
RATIO OF CIRCUMFERENTIAL SPEED
(FIRST SUPPLYING ROLLER / DEVELOPING ROLLER)
(SECOND SUPPLYING ROLLER NOT USED)
SOLID BLACK "TOP" (AFTER VOLTAGE CHANGE)
SOLID BLACK "BOTTOM" (AFTER VOLTAGE CHANGE)
SOLID BLACK "TOP" (BEFORE VOLTAGE CHANGE)
SOLID BLACK "BOTTOM" (BEFORE VOLTAGE CHANGE)

FIG.16A

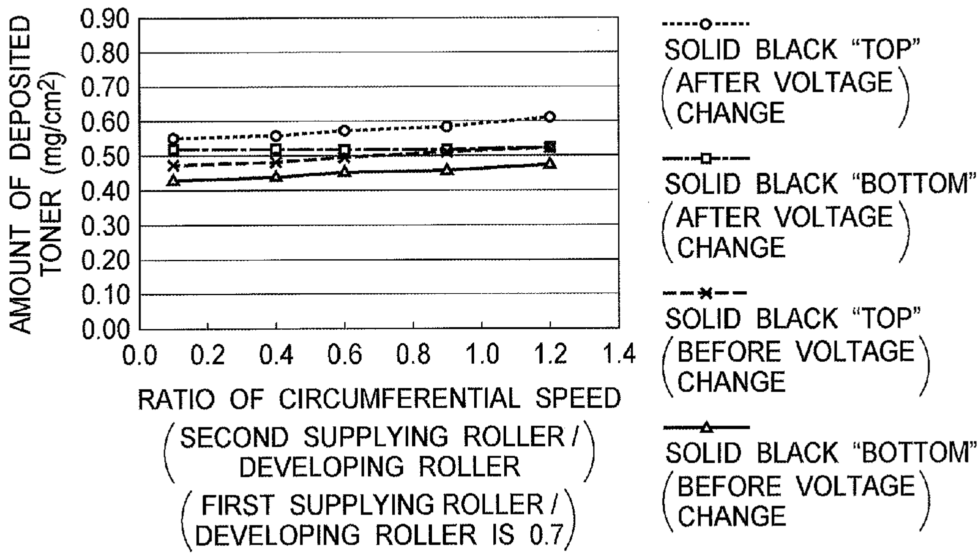

FIG.16B

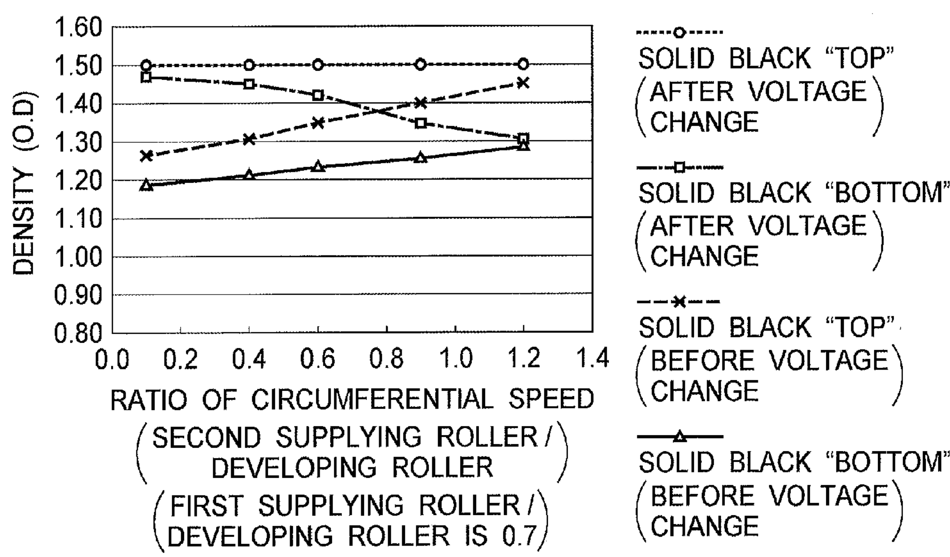

FIG.17

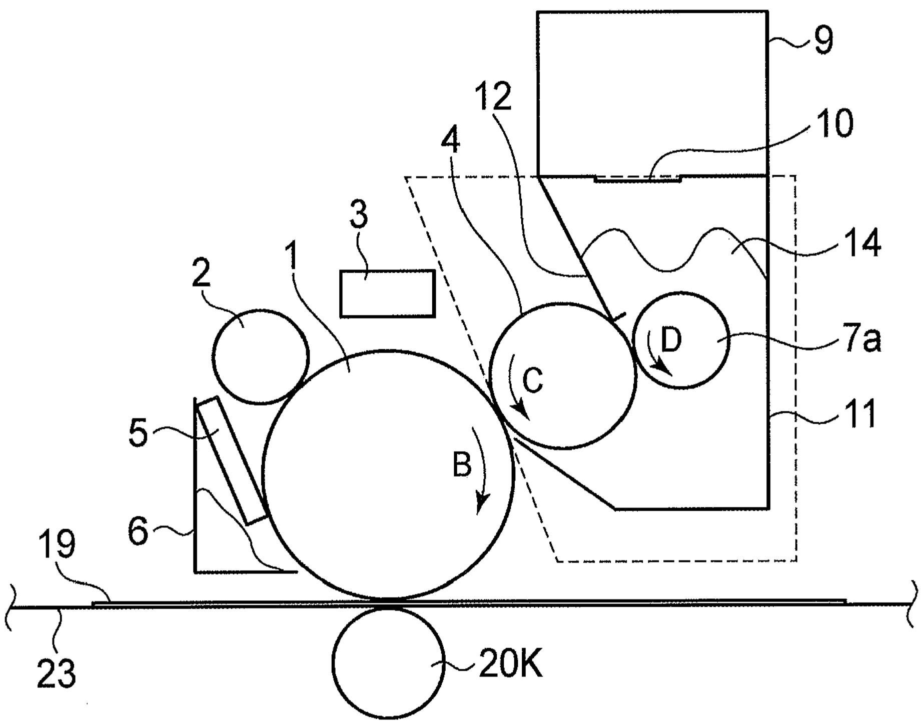

IMAGE FORMING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image forming apparatus including image forming apparatus such as electrophotographic printers and copying machines.

2. Description of the Related Art

Existing image forming apparatus include a photoconductive drum and a developing roller. An electrostatic latent image is formed on the photoconductive drum. The developing roller rotates in contact with the photoconductive drum to supply a developer material to the photoconductive drum, thereby developing the electrostatic latent image into a toner image. Some existing image forming apparatus include two developer material supplying rollers that rotate in contact with a developing roller to supply a developer material to the developing roller.

Japanese Patent Publication No. H10-39628 (page 4 and FIG. 1) discloses one such image forming apparatus.

However, if a high density image is printed on recording paper, the use of the dual supplying rollers can still cause some difference in image density between the lading portion and trailing portion of the recording paper.

SUMMARY OF THE INVENTION

An object of the invention is to solve the problem of using two supplying rollers.

Another object of the invention is to provide an image forming apparatus that employs two supplying rollers but is capable of printing with high print quality.

Still another object of the invention is to provide an image forming apparatus capable of minimizing the difference in image density between a leading portion of a page of the recording paper and a trailing portion.

An image forming apparatus includes a developer bearing body and first and second supplying members. The developer bearing body supplies a developer material to an image bearing body that bears an electrostatic latent image thereon, thereby developing the electrostatic latent image with the developer material. First and second supplying members supply the developer material to the developer bearing body. The second supplying member is disposed upstream of the first supplying member with respect to rotation of the developer bearing body. The circumferential speed of the first supplying member is higher than the circumferential speed of the second supplying member.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limiting the present invention, and wherein:

FIG. **1** illustrates the general configuration of an image forming apparatus according to a first embodiment;

FIG. **2** illustrates the general configuration of the image forming section for black images together with a transfer belt and a transfer roller;

FIG. **3** illustrates the positional relationship among a developing roller, a first supplying roller, and a second supplying roller;

FIG. **4** is a block diagram illustrating the respective sections of the image forming apparatus, pertinent to the present invention;

FIG. **5** is a flowchart illustrating an image density setting operation;

FIG. **6** is a partial expanded view of a nip formed between the developing roller and the first supplying roller;

FIG. **7** illustrates the relationship between the ratio of the circumferential speed of the first supplying roller to that of the developing roller and the amount of toner deposited on the developing roller when a printing operation is performed using only the first supplying roller;

FIG. **8** illustrates the relationship between the ratio of the circumferential speed of the first supplying roller to that of the developing roller and the density of image printed on the recording paper when a printing operation is performed using only the first supplying roller;

FIGS. **9**A and **9**B illustrate the test results of a printing operation using the first and second supplying rollers;

FIG. **10**A illustrates the relationship between the ratio of the circumferential speed of the first supplying roller to that of the developing roller and the amount of toner deposited on the developing roller when a printing operation is performed using the first and second supplying rollers;

FIG. **10**B illustrates the relationship between the ratio of the circumferential speed of the first supplying roller to that of the developing roller and the image density when a printing operation is performed using the first and second supplying rollers;

FIG. **11** is a block diagram illustrating the respective sections of an image forming apparatus according to a second embodiment, pertinent to the present invention;

FIG. **12** is a flowchart illustrating an image density setting operation performed in the image forming apparatus of FIG. **11** prior to a printing operation;

FIG. **13** illustrates the positional relation between the developing roller **4** and the first supplying roller **7**;

FIG. **14** illustrates the relationship between the ratio of the circumferential speed of the first supplying roller to that of the developing roller and the amount of toner deposited on the developing roller when a printing operation is performed using only the first supplying roller;

FIG. **15** illustrates the relationship between the ratio of the circumferential speed of the first supplying roller to that of the developing roller and the amount of toner deposited on the developing roller when a printing operation is performed using only the first supplying roller;

FIG. **16**A illustrates the relationship between the ratio of the circumferential speed of the second supplying roller to that of the developing roller and the amount of toner deposited on the developing roller;

FIG. **16**B illustrates the relationship between the ratio of the circumferential speed of the second supplying roller to that of the developing roller and the density of an image printed on the recording paper; and

FIG. **17** illustrates a configuration in which the second supplying roller is not used.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described in detail with reference to the accompanying drawings. It will be understood that it is not intended to limit the invention to the accompanying drawings.

{Construction}

FIG. **1** illustrates the general configuration of an image forming apparatus **100** according to a first embodiment.

The image forming apparatus **10** takes the form of, for example, an electrophotographic printer that utilizes a plurality of image-forming sections **40**K, **40**Y, **40**M, and **40**C in tandem. The image forming sections **40**K, **40**Y, **40**M, and **40**C form images of corresponding colors, respectively: black (K), yellow (Y), magenta (M), and cyan (C). A transfer belt **23** is disposed about a drive roller **21** and a driven roller **22**, and defines a paper-transporting path. A transfer unit **25** is disposed along the paper-transport path, facing the image forming sections **40**K, **40**Y, **40**M, and **40**C. The recording paper **19** is fed from, a paper cassette (not shown), and is electrostatically attracted to the transfer belt **23**. The recording paper **19** is then transported by the transfer belt **23** through the respective image forming sections in a direction shown by arrow A to a fixing section **30** located near a downstream end of the transport path. As the recording paper **19** passes through the fixing section **30**, the toner image on the recording paper **19** are fused into a permanent image.

The image forming sections **40**K, **40**Y, **40**M, and **40**C are aligned along the paper-transport path. Each of the image forming sections **40**K, **40**Y, **40**M, and **40**C may be substantially identical; for simplicity only the operation of the image forming section **40**K for forming black images will be described, it being understood that the other image forming sections **40**Y, **40**M, and **40**C may work in a similar fashion.

FIG. **2** illustrates the general configuration of the image forming section **40**K together with the transfer belt **23** and transfer roller **20**K.

The image forming section **40**K includes a photoconductive drum **1** as an image bearing body on which an electrostatic latent image is formed. The photoconductive drum **1** rotates in a direction shown by arrow B. A charging roller **2** as a charging member, an LED head **3** as an exposing section, a developing section **15**, and a cleaning blade **5** are disposed around the photoconductive drum **1** in this order. The charging roller **2** rotates in pressure contact with the photoconductive drum **1** to charge the surface of the photoconductive drum **1**. The LED head **3** illuminates the charged surface of the photoconductive drum **1** to form an electrostatic latent image on the surface of the photoconductive drum **1**.

The developing section **15** supplies toner of a corresponding color (black) to develop the electrostatic latent image into a toner image. The cleaning blade **5** scrapes the surface of the photoconductive drum **1** to remove the residual toner after transfer of the toner image onto the recording paper **19** on the transfer belt **23**. The cleaning blade **5** is formed of an elastic material and has an edge in pressure contact with the surface of the photoconductive drum **1**. The rotatable members in the image forming section **40**K are driven by a drive force transmitted from a drive source (not shown) via, for example, gears (not shown).

The developing section **15** includes a toner tank **9**, a toner room **11**, a developing roller **4** as a developer bearing body, a first supplying roller **7** as a first supplying member, and a second toner supplying roller **8** as a second supplying member, and a developing blade **12** as a developer limiting member. The toner tank **9** stores toner **14** as a developer material. The image bearing body, first supplying roller, and second supplying roller are disposed around the developing roller in this order so that the image bearing body is upstream of the second supplying roller with respect to rotation of the developing roller, and the second supplying roller is upstream of the first supplying roller. The toner room **11** holds the toner **14** supplied from the toner tank **9**. The developing blade forms a thin layer of the toner **14** on the developing roller **4**. The developing roller **4** holds a thin layer of toner thereon, and rotates in contact with the photoconductive drum **1**, thereby developing the electrostatic latent image into a toner image. The first supplying roller **7** and second supplying roller **8** supply the toner **14** to the developing roller **4**.

The first supplying roller **7** and second supplying roller **8** parallel the photoconductive drum **1**. The first supplying roller **7**, second supplying roller **8**, and photoconductive drum **1** rotate in directions shown by arrows D, E, and C, respectively. The developing blade **12** is positioned relative to the developing roller **4** so that the folded end portion of the developing blade **12** parallels the photoconductive drum **1** and is pressed against the circumferential surface of the developing roller **4** under uniform pressure across the length of the developing roller **4**. The rotatable members in the developing section **15** are driven by a drive force transmitted from a drive source (not shown) via, for example, gears (not shown).

The configuration of the toner **14**, developing roller **4**, first supplying roller **7**, and second supplying roller **8** will be described in detail. FIG. **3** illustrates the positional relationship among the developing roller **4**, and first supplying roller **7** (or the second supplying roller **8**).

The toner **14** is a pulverized developer material and has an average particle diameter of 8 μm. The toner **14** is formed of polyester resin and contains a coloring agent, a charge control agent, and a releasing agent as internal additives. An external additive, for example, hydrophobic silica, is added to the surface of the particles of the toner **14**. The developing roller **4** includes a metal shaft **4***a* and an elastic body **4***b* formed on the metal shaft. For example, the metal shaft **4***a* has a diameter of 10 mm. The elastic body is formed of semi-conductive urethane rubber and has a thickness of 3 mm and a rubber hardness of 70 on the Asker C scale. The first and second supplying rollers **7** and **8** are of an identical configuration. Each supplying roller includes a metal shaft **7***a* or **8***a* having a diameter of 6 mm, and a foamed body **7***b* or **8***b* formed of foamed silicone having a thickness of 3.5 mm, and a hardness of 50 on the Asker F scale.

Referring to FIG. **3**, the distance L between the rotational axis of the developing roller **4** and the rotational axis of the first supplying roller **7** (or second supplying roller **8**) is selected to be 13.5 mm. The depth D of the nip formed between the first supplying roller **7** (or supplying roller **8**) and the developing roller **4** is 1.0 mm. The depth D is given by equation (1) as follows:

$$D=(r1+r2)-L \quad \text{Eq. (1)}$$

where D is the depth of the nip, **r1** is the radius of the developing roller **4**, r2 is the radius of the first supplying roller **7** (or second supplying roller **8**), and L is the distance between the rotational axes X1 and X2 of the first supplying roller **7** (or second supplying roller **8**) and the developing roller **4**.

Referring back to FIG. **1**, the transfer rollers **20**K, **20**Y, **20**M, and **20**C parallel the photoconductive drums of corresponding image forming sections **40**K, **40**Y, **40**M, and **40**C, respectively, with the transfer belt **23** held therebetween in a sandwiched relation. The transfer rollers **20**K, **20**Y **20**M, and **20**C receive a high voltage, thereby developing an electric field between the transfer roller and the photoconductive drum **1** so that the toner image is transferred from the photoconductive drum **1** onto the recording paper **19**.

A cleaning blade **26** scrapes the outer surface of the transfer belt **23** to remove residual toner from the transfer belt **23**, thereby collecting the residual toner into a waste toner reservoir **27**. A density sensor **28** is located in the vicinity of the downstream end of the transfer belt **23** with respect to the paper transport path.

The fixing section **30** incorporates a heat roller **31** and a backup roller **32** in pressure contact with the heat roller **30** to define a fixing point therebetween. As the recording paper **19** passes through the fixing point, the toner image on the recording paper **19** is fused into a permanent image under heat and pressure. The recording paper **19** is then discharged onto a stacker (not shown).

{Control Diagram}

FIG. **4** is a block diagram illustrating the respective sections of the image forming apparatus **100** pertinent to the present invention. The control system will be described with reference to FIGS. **1** and **2**.

A printing controller **50** performs the overall control of the image forming apparatus **100**. The printing controller **50** communicates signals and data with a human interface **53** and an interface **52** that receives print data from a host apparatus **51**. A memory **54** includes a ROM **55** and a RAM **56**. The ROM **55** stores Table 1 that lists voltages applied to the respective rollers. The RAM **56** holds a variety of data necessary for the operation of the image forming apparatus **100**. The memory **54** communicates with the printing controller **50**.

The printing controller **50** also communicates with and a process controller **60** and a variety of sensors **58** that detect the recording paper **19**. The developing voltage controller **61** controls the voltage applied to the developing roller **4** and a supplying voltage controller **62** controls the voltages applied to the first and second supplying rollers **7** and **8**. A blade voltage controller **63** controls the voltage applied to the developing blade **12**. A charging voltage controller controls the voltages applied to the charging rollers of the respective image forming sections. An exposure controller **65** controls the respective LED heads **3** of the respective image forming sections.

A drum motor controller **66** drives a drum motor **70** that drives the photoconductive drums of the respective image forming sections **40***k*, **40**Y, **40**M, and **40**C to rotate in the B direction shown in FIG. **2**. The photoconductive drum **1**, developing roller **4**, first supplying roller **7**, and second supplying roller **8** of each image forming section have gears at one longitudinal end portions thereof. The gears are in meshing engagement with each other, so that when the photoconductive drum **1** is driven in rotation, the developing roller **4**, first supplying roller **7**, and second supplying roller **8** are driven to rotate in the C, D, and E directions. The density sensor **28** is controller by a density sensor controller **67** and detects an image density or the density of an image formed on the transfer belt **23**, and communicates with the printing controller **50**.

{Printing Operation}

The operation of the image forming apparatus **100** will be described with reference to FIGS. **1**, **2**, and **4**.

The charging roller **2** charges the surface of the photoconductive drum **1** under control of the charging voltage controller **64**. As the photoconductive drum **1** rotates in the B direction, the charged surface **3** reaches a position immediately below the LED head **3**, where the LED head **3** illuminates the charged surface in accordance with the print data to form an electrostatic latent image. The electrostatic latent image is developed by the developing section **15** into a toner image.

The recording paper **19** fed from the paper cassette (not shown) is transported by the transfer belt **23** toward the transfer roller **20**K. When the toner image reaches a transfer point defined between the photoconductive drum **1** and the transfer roller **20**K, the toner image is transferred onto the recording paper **19** on the transfer belt **23**. The transfer of toner images is performed in the image forming sections **40**K, **40**Y, **40**M, **40**C in sequence, so that the toner images of corresponding colors are overlaid one over the other in registration to form a full color image.

The recording paper **19** carrying the full color toner image thereon is then transferred by the transfer belt **23** to the fixing section **30**. The toner image is fused under heat and pressure in the fixing section **30**. The recording paper **19** then leaves the fixing section **30** and is further transported to the stacker. After the recording paper **19** has left the transfer belt **23**, the cleaning blade **26** removes the residual toner from the transfer belt **23**.

{Density Setting Operation}

FIG. **5** is a flowchart illustrating an image density setting operation prior to a printing operation.

The image forming apparatus **100** performs the image density setting process prior to the printing operation. This process will be described with reference to the flowchart shown in FIG. **5**. The image density setting process is performed in each of the image forming sections **40**K, **40**Y, **40**M, and **40**C. The process will be described, by way of example, with reference to the image forming section **40**K.

The printing controller **50** detects when the image forming apparatus **100** is turned on (S**101**), and causes the motor controller **66** to drive the drum motor **70** to rotate at a predetermined rotational speed (S**102**). For example, the gear ratios are selected such that when the photoconductive drum **1** is driven to rotates at a circumferential speed of 130 mm/s, the developing roller **4** rotates at a circumferential speed of 156 mm/s, the first supplying roller **7** rotates at a circumferential speed of 109 mm/s, and the second supplying roller **8** rotates at a circumferential speed of 93 mm/s. In other words, the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** is selected to be 0.7. The ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** is selected to be 0.6.

The printing controller **50** drives the charging voltage controller **64**, developing voltage controller **61**, and supplying voltage controller **62** to apply voltages of −1150 V, −200 V, −300 V, and −300 V to the charging roller **2**, developing roller **4**, first supplying roller **7**, and second supplying roller **8**, respectively (S**103**).

The printing controller **50** performs a density correction in which the image density is adjusted to a value equivalent to an optical density OD=1.5 measured with the Model X-Rite® 528 Color Reflection Densitometer available from X-Rite, Inc. (S**104**).

After the image density correction, the image forming apparatus **100** is then ready to perform the normal printing operation, and the printing controller **50** receives the print data from the host apparatus **51** via the interface **52** (S**105**). Printing is then performed (S**106**).

The image density is adjusted as follows:

A target image density equivalent to OD=1.5 is selected.

Test patch is a toner image used for testing the image density and is formed in accordance with a density setting. A test patch that occupies the entire printable area on the recording paper **19** is formed in the image forming section with reference voltages applied to the respective rollers at S**103**. The test patch is then transferred onto the transfer belt **23**. The density sensor **28** reads the image density of the test patch. For example, if the image density read by the density sensor **28** is equivalent to OD=1.4, the image density is 0.1 lighter than the target image density equivalent to OD=1.5. The reference voltages applied to the respective rollers at S**103** are corrected for increasing the developing efficiency. Correction bias voltage data applied to the charging roller **2**, developing roller **4**, first supplying roller **7**, and second supplying roller for darkening the image density equivalent to that measured with X-Rite by 0.1 is read from Table 1 for correction stored in the ROM **55**.

TABLE 1

OD VALUE	1.3	1.4	1.5	1.6
CHARGING VOLTAGE (V)	−1210	−1180	−1150	−1120
DEVELOPING VOLTAGE (V)	−260	−230	−200	−170
SUPPLYING VOLTAGE (V)	−330	−330	−300	−270

Thus, the charging roller **2**, developing roller **4**, first supplying roller **7**, and second supplying roller **8** receive voltages of −1180 V, −230 V, −330 V, and −330 V respectively, thereby correcting the image density to a value equivalent to OD=1.5. It is to be noted that the respective voltages are applied while maintaining the differences in voltage among the charging roller **2**, developing roller **4**, first supplying roller **7**, and second supplying roller **8** unchanged.

Table 1 for correction stored in the ROM **55** lists correction data that produce a corrected image density equivalent to OD=1.5 measured with the X-Rite 528 Color Reflection Densitometer. It is to be noted that the image density correction at S**104** is not performed by actually using the X-Rite 528 Color Reflection Densitometer.

{Ratio of Circumferential Speed, Amount of Deposited Toner, and Image Density}

A description will be given of the relationship between the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** and the ratio of the circumferential speed of the second supplying roller **7** to that of the developing roller **4***b*.

The operation in which the first supplying roller supplies the toner **14** to the developing roller **4** will be described.

FIG. **6** is a partial expanded view of a nip formed between the developing roller **4** and the first supplying roller **7**.

The developing roller **4** and the first supplying roller **7** rotate in the C and D directions, respectively, as shown in FIG. **6**. The first supplying roller **7** rotates in the D direction to scrape the residual toner **14***a* after developing the electrostatic latent image at a scraping area **17** while supplying the toner **14** to the developing roller **4** at a contact point **16**. The width of the scraping area **17** is 5.56 mm if the nip depth D between the developing roller **4** and first supplying roller **7** is 1.0 mm. In order for the first supplying roller **7** to scrape the residual toner **14***a*, the width of the scraping area **17** needs to be larger than 4 mm, in which case the required nip depth D would be 0.6 mm. Conversely, if the width of the scraping area **17** is larger than 7 mm, a larger rotational torque is required which may cause the gear teeth to skip. Thus, the nip depth D should be set equal to or less than 1.4 mm and the width of the scraping area **17** should be, for example, 7 mm.

A description will be given of the relationship between the ratios of the circumferential speeds of the first and second supplying rollers **7** and **8** to that of the developing roller **4** and the amount of toner deposited on the developing roller **4** and the relationship between the ratios of the circumferential speeds of the first and second supplying rollers **7** and **8** to that of the developing roller **4** and the image density.

The test was conducted as follows:

The density correction at S**104** (FIG. **5**) is performed to adjust the image density of a solid black test patch to the target image density equivalent to OD=1.5.

Solid black "top" is a leading portion of a solid black patch printed on the recording paper **19**. Solid black "bottom" is a trailing portion of the solid black patch printed on the recording paper **19**. The amount of toner (mg/cm^2) deposited to the developing roller **4** for printing the solid black "top" shown in FIG. **7** is the amount of toner deposited on the developing roller **4** to develop a trailing portion of a solid black image printed on A4 size recording paper **19**. When printing is performed on the A4 size recording paper in a landscape orientation, the developing roller **4** needs to make about four complete rotations. Thus, the solid black "top" is the amount of toner deposited on the developing roller **4** during the first rotation of the developing roller **4**, and the solid black "bottom" is the amount of toner deposited on the developing roller **4** during the fourth rotation of the developing roller **4**.

The ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** is selected to be 0.7, and the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** is selected to be 0.6. It is assumed that high quality images can be obtained if the target image density is equivalent to OD=1.5 and the difference in the density of an actual image between the solid black "top" and solid black "bottom" is equivalent to OD=1.5±0.1. It is to be noted that the image forming apparatus is configured such that the circumferential speed of the first supplying roller **7** and second supplying roller **8** can be selectively set.

{Configuration with a Single Supplying Roller}

The image forming apparatus shown in FIG. **17** has only a single supplying roller **7***a*. Using this image forming apparatus, a comparison test was conducted. The test results will be described with reference to FIG. **7**.

FIG. **7** illustrates the relationship between the ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4** and the amount of toner deposited to the developing roller **4**.

Measurements were made under the following conditions. The circumferential speed of the developing roller **4** is maintained at 156 mm/s and the circumferential speed of the first supplying roller **7***a* is varied such that the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** changes from 0.1 to 1.2.

Referring to FIG. **7**, the amount of toner required for printing the solid black "bottom" increases with increasing ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4**. The amount of toner for printing the solid black "bottom" increases because the toner supplied to the contact point **16** (FIG. **6**) increases with the circumferential speed of the supplying roller **7***a*.

The difference in the amount of toner deposited on the developing roller **4** between the solid black "bottom" and solid black "top" increases with the ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4**. This is due to the fact that as the circumferential speed of the supplying roller **7***a* increases, the nip depth D between the developing roller **4** and supplying roller **7***a* decreases so that the supplying roller **7***a* and the developing roller **4** repel each other to decrease the contact area and therefore the amount of toner scraped off the developing roller **4** decreases.

As described above, if only a single supplying roller **7***a* is employed, the efficiency in scraping or removing the toner from the developing roller **4** decreases, so that the amount of toner deposited on the developing roller **4** increases and the difference in the amount of toner deposited on the developing roller **4** between the solid black "top" and solid black "bottom" increases. Conversely, if the ratio of the circumferential speed decreases, the amount of toner removed from the developing roller **4** increases so that the difference in the amount of toner deposited on the developing roller **4** between the solid black "top" and the solid black "bottom" decreases and the amount of toner deposited on the developing roller **4** also decreases.

{Configuration with a Single Supplying Roller}

FIG. **17** illustrates a configuration in which the second supplying roller **8** is not used. A test was conducted to evaluate the relationship between the ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4** and the density of an image printed on the A4 size recording paper **19**. FIG. **8** illustrates the test results.

The density of a printed image was measured for the ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4** in the range of 0.1 to 0.2. The developing roller **4** was maintained at a fixed circumferential speed (e.g., 156 mm/s) during each measurement. Solid black "top" is a leading portion of a solid black patch printed on the A4 size recording paper **19**. Solid black "bottom" is a trailing portion of a solid black patch printed on the A4 size recording paper **19**. The image density of solid black "top" shown in FIG. **8**, which is equivalent to an OD value measured with the Model X-Rite® 528 Color Reflection Densitometer, is the image density of the leading portion of a solid black image printed on the A4 size recording paper **19**. The image density OD of solid black "bottom" shown in FIG. **8** is the image density of the trailing portion of the solid black image printed on the A4 size recording paper **19**.

The difference in image density between the solid black "top" and solid black "bottom" decreases with increasing ratio of circumferential speed of the supplying roller **7***a* to that of the developing roller **4**, reaching a minimum difference of OD=0.2 which is still larger than a target difference of OD=0.1. In addition, when the ratio of circumferential speed of the supplying roller **7***a* to that of the developing roller **4** decreases below 0.6, the image density of solid black "top" becomes lower than a value equivalent to OD=1.5. This implies that when the ratio of circumferential speed of the supplying roller **7***a* to that of the developing roller **4** decreases below 0.6, the amount of toner deposited to the developing roller **4** decreases below 0.60 mg (FIG. **7**), preventing the image density from increasing even if the developing efficiency is increased by increasing the developing voltage.

The test results reveal that when only the single supplying roller **7***a* is used, even if the ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4** is adjusted, it is difficult to implement the difference in image density between the solid black "top" and solid black "bottom" lower than OD=0.1 while maintaining the image density of the solid black "top" to a level or value equivalent to OD=1.5.

{Configuration with Dual Supplying Roller}

Another test was conducted using the first supplying roller **7** and the second supplying roller **8** to evaluate the relationship between the ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4**, the amount of toner deposited on the developing roller **4**, and the image density or the density of an image printed on the A4 size recording paper.

FIGS. **9**A and **9**B illustrate the test results. The ratio of the circumferential speed (e.g., 109 mm/s) of the first supplying roller **7** to that (e.g., 156 mm/s) of the developing roller **4** was selected to be 0.7, and the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **8** was varied from 0.1 to 1.2.

In FIG. **9**A, the amount of toner deposited on the developing roller **4** for printing the solid black "top" is the amount of toner used to print a leading portion of a solid black patch printed on the recording paper **19** with respect to the direction of travel of the recording paper **19**. The amount of toner deposited on the developing roller **4** for developing a solid black "bottom" is the amount of toner used to print a trailing portion of a solid black patch on the recording paper **19**. When printing is performed on the A4 size paper in a landscape orientation, the developing roller **4** needs to make about four complete rotations. Thus, the solid black "top" is the amount of toner deposited on the developing roller **4** during the first rotation of the developing roller **4**, and the solid black "bottom" is the amount of toner deposited on the developing roller **4** during the fourth rotation.

Referring back to FIG. **2**, the first supplying roller **7** supplies the toner **14** to the developing roller **4**. The amount of toner deposited on the developing roller **4** can be at least 0.55 mg for developing the solid black "bottom" as shown in FIG. **9**A even if the ratio of the circumferential speed of the second supplying roller **8** is decreased to 0.1. Also, the first and second supplying rollers **7** and **8** scrape the residual toner **14***a* from the developing roller **4**, and therefore the difference in the amount of toner deposited on the developing roller **4** between the solid black "top" and solid black "bottom" can be below 0.05 mg.

In FIG. **9**B, the image density OD of the solid black "top" is the image density of the leading portion of a solid black image printed on the A4 size recording paper **19**. Likewise, the image density OD of solid black "bottom" is the image density of the trailing portion of the solid black image printed on the A4 size recording paper **19**.

Referring to FIG. **9**B, when the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** is 0.7, if the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** is in the range of 0.1 to 0.6, the image density of the solid black "top" can be maintained at OD=1.5 and the difference in image density between the solid black "top" and solid black "bottom" can be maintained below OD=0.1. As described above, the difference in image density between the solid black "top" and solid black "bottom" can be maintained below OD=0.1. This is considered due to the increase in the amount of scraped toner resulting from the narrow range (i.e., 0.1 to 0.6) of the ratio of circumferential speed of the second supplying roller **8** to that of the developing roller **4**.

FIG. **10**A illustrates the relationship between the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** and the amount of toner deposited on the developing roller **4**.

FIG. **10**B illustrates the relationship between the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** and the density of the printed image.

The ratio of the circumferential speed (e.g., 93 mm/s) of the second supplying roller **8** to that (e.g., 156 mm/s) of the developing roller **4** was selected to be 0.6, and the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **8** was varied from 0.1 to 1.3.

The amount of toner deposited on the developing roller **4** shown in FIG. **10**A is defined in the same manner as in that shown in FIG. **9**A. Likewise, the image density shown in FIG. **10**B is defined in the same manner as in that shown in FIG. **9**B.

Referring to FIG. **10**B, when the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** is 0.6, if the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** is in the range of 0.7 to 1.3, the image density of the solid black "top" can be maintained to a level equivalent to OD=1.5 and the difference in image density between the solid black "top" and solid black "bottom" can be maintained not higher than a level equivalent to OD=0.1.

As described above, in the present invention, print results are good if the image density of the solid black "top" is higher than OD=1.5 and the difference in image density between the solid black "top" and the image density of the solid black "bottom" is not higher than OD=0.1. Conversely, print results are poor if the image density of the solid black "top" is not higher than OD=1.5 or the difference in image density between the solid black "top" and solid black "bottom" is higher than OD=0.1. The test results reveal that when the second supplying roller **8** is positioned upstream of the first supplying roller **7** with respect to the rotation of the developing roller **4**, the print results can be good if the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** is smaller than the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4**.

As described above, the image forming apparatus **100** according to the first embodiment employs two supplying rollers for a single developing roller. The two supplying rollers are disposed side by side along the rotational direction of the single developing roller, and rotate at different ratios of the circumferential speed to that of the developing roller. The ratio of the circumferential speed of a second supplying roller upstream with respect to rotation of the developing roller is selected to be smaller than that for a first supplying roller downstream of the second supplying roller. This configuration provides sufficient supply of toner to the developing roller and is sufficiently effective in scraping the residual toner from the developing roller, so that the difference in image density within a page of the recording paper **19** can be minimized for high quality print image.

Second Embodiment

FIG. **11** is a block diagram illustrating the respective sections, which are pertinent to the present invention, of an image forming apparatus **200** according to a second embodiment.

The second embodiment differs from the first embodiment in that a counter **201** is additionally employed and a printing process is performed in a different manner using the counter **201**. Elements similar to those of the first embodiment have been given like reference characters and their description is omitted. The second embodiment will be described mainly in terms of portions different from the first embodiment. The pertinent portion of the configuration of the image forming apparatus **200** is common to that of the image forming apparatus **100** shown in FIGS. **1** and **2**, and therefore the description will be made with reference to FIGS. **1** and **2**.

The counter **201** counts the cumulative number of printed pages, N. The cumulative number of pages N is stored in a RAM **56** and is updated as the cumulative number of pages N increases. The counter **201** and RAM **56** constitute a counting section.

{Density Setting Operation}

FIG. **12** is a flowchart illustrating an image density setting operation performed in the image forming apparatus **200** prior to a printing operation. The image density setting operation will be described with reference to FIG. **12**. Respective image forming sections **40**K, **40**M, **40**Y, and **40**C perform the image density setting operation in the same manner. Each of the image forming sections **40**K, **40**M, **40**Y, and **40**C may be substantially identical; for simplicity only the operation of the image forming sections **40**K for forming black images will be described, it being understood that the other image forming sections **40**M, **40**Y, and **40**C may work in a similar fashion.

A printing controller **50** detects power-up of the image forming apparatus **200** when the image forming apparatus **200** is turned on (S**201**). The printing controller **50** then drives a motor controller **66**, thereby causing respective drum motors **70** to rotate at a predetermined circumferential speed (e.g., 130 mm/s) (S**202**). The gear ratios among the developing roller **4** and first and second supplying rollers **7** and **8** are selected such that when the photoconductive drum **1** rotates at a circumferential speed of 130 mm/s, the developing roller **4**, the first supplying roller **7**, and second supplying roller **8** rotate at circumferential speeds of 156 mm/s, 109 mm/s, and 93 mm/s, respectively. In other words, the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4**K is 0.7, and the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4**K is 0.6.

Next, the printing controller **50** reads the cumulative number of printed pages N from the RAM **56** (S**203**), and then makes a decision to determine whether the cumulative number of printed pages N is smaller than 10,000 (S**204**).

If N is smaller than 10,000 (YES at S**204**), the printing controller **50** refers to Table 2 held in the ROM **55** to read a voltage of −300 V, and applies the voltage of −300 V to both the first and second supplying rollers **7** and **8** (S**205**). If N≥10,000 (NO at S**204**), the printing controller **50** reads a voltage of −400 V from Table 2 and applies the voltage to the first supplying roller **7** and second supplying roller **8** (S**206**). On other words, the voltage is switched from −300 V to −400 V. In S**205** and S**206**, a voltage of −1150 V is applied to a charging roller **2** and a voltage of −200 V is applied to the developing roller **4**.

TABLE 2

VOLTAGE (V)	
V1	V2
−300	−400

The printing controller **50** then performs an image density correction so that image density or the density of a printed image is a level or value equivalent to OD=1.5 (S**207**). The image density correction is performed without changing the differences in voltage among the charging roller **2**, the developing roller **4**, the first supplying roller **7**, and the second supplying roller **8**.

After the image density correction, the printing controller **50** receives print data from a host apparatus **51** via an interface **52** (S**208**), and performs the normal printing operation of the image forming apparatus **200** (S**209**).

{Change in Ability to Supply Toner and to Scrape Toner}

FIG. **13** illustrates the positional relation between the developing roller **4** and the first supplying roller **7**. The ability of the first supplying roller **7** to supply the toner and to scrape the toner varies with time. The change in the ability will be described with reference to FIG. **13**.

As the foamed part on the outer peripheral portion of the supplying roller **7** wears with time, the outer diameter decreases as shown in dotted line in FIG. **13**, causing the outer surface area to decrease. As a result, less toner is supplied to the developing roller **4** and the depth of a nip formed between the supplying roller **7** and the developing roller **4** also decreases causing less residual toner **14***a* to be scraped. Generally speaking, the higher the circumferential speed of the supplying roller is, the further the supplying roller wears. Thus, the ability of the supplying roller to supply the toner and to scrape the residual toner prominently decreases.

A description will be given of the relation among the ratios of the circumferential speed of the first and second supplying rollers **7** and **8** to that of the developing roller **4**, the amount of toner deposited on the developing roller **4**, and the image density when the voltages applied to the first and second supplying rollers **7** and **8** are changed from −300 V to −400 V.

It is assumed that the charging roller **2** receives a voltage of −1150 V and the developing roller receives a voltage of −200 V before and after the voltages applied to the first and second supplying rollers **7** and **8** are changed.

With the aforementioned voltages applied to the charging roller **2**, developing roller **4**, and the first and second supplying rollers **7** and **8**, the image density correction is performed as in S**207** so that the image density of the solid black "top" is equal to the target image density of OD=1.5. The voltages applied to the charging roller **2**, developing roller **4**, and the first and second supplying rollers **7** and **8** are adjusted while maintaining the differences in voltage among the charging roller **2**, developing roller **4**, and the first and second supplying rollers **7** and **8** unchanged.

During the image density correction, the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** is 0.7, and the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** is 0.6. In the present invention, print results are good if the image density of the solid black "top" is OD=1.5 and the difference in image density between the solid black "top" and the solid black "bottom" is not higher than OD=0.1. The image forming apparatus used in the test is configured such that the circumferential speeds of the first and second supplying rollers **7** and **8** can be selectively set.

{Configuration with a Single Supplying Roller}

Using the configuration shown in FIG. **17**, a test was conducted to evaluate the relationship between the ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4** and the amount of toner deposited on the developing roller **4**. The test results will be described with reference to FIG. **14**.

The image density was measured for the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** in the range of 0.1 to 0.2. The developing roller **4** was maintained at a fixed circumferential speed (e.g., 156 mm/s) during each measurement. Solid black "top" is a leading portion of a solid black patch printed on the recording paper **19**. Solid black "bottom" is a trailing portion of the solid black patch printed on the recording paper **19**. The amount of toner deposited on the developing roller **4** for developing the solid black "top" shown in FIG. **14** is the amount of toner deposited on the developing roller **4** for the leading portion of a solid black image printed on the A4 size recording paper **19**. The amount of toner deposited on the developing roller **4** for developing the solid black "top" shown in FIG. **14** is the amount of toner deposited on the developing roller **4** for developing the trailing portion of the solid black image printed on the A4 size recording paper **19**.

When printing is performed on the A4 size paper in a landscape orientation, the developing roller **4** needs to make about four complete rotations. Thus, the solid black "top" is the amount of toner deposited on the developing roller **4** during the first rotation of the developing roller **4**, and the solid black "bottom" is the amount of toner deposited on the developing roller **4** during the fourth rotation of the developing roller **4**.

Referring to FIG. **14**, if the voltage applied to the first supplying roller **7** is switched from −300 V to −400 V when printing has been performed on 10,000 pages, the amounts of the toner deposited on the developing roller **4** for the solid black "top" and solid black "bottom" will change. That is, the amount of toner is larger after the voltage is switched from −300 V to −400 V than before the voltage is switched from −300 V to −400 V. The amount of toner increases with increasing ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4**. However, if only the first supplying roller **7** is used to supply the toner to the developing roller **4**, the problem of the test results shown in the first embodiment (FIG. **7**) still remains unsolved.

FIG. **17** illustrates a configuration in which the second supplying roller **8** is not used. A test was conducted to evaluate the relationship between the ratio of the circumferential speed of the supplying roller **7***a* to that of the developing roller **4** and the image density or the density of an image printed on the A4 size recording paper **19**. FIG. **15** illustrates the test results.

The image density was measured for the ratio of the circumferential speed from 0.1 to 0.2. The developing roller **4** was maintained at a fixed circumferential speed (e.g., 156 mm/s) during each measurement. Solid black "top" is a leading portion of a solid black patch printed on the recording paper **19**. Solid black "bottom" is a trailing portion of a solid black patch printed on the recording paper **19**. The image density OD of solid black "top" shown in FIG. **15** is the image density of the leading portion of a solid black image printed on the A4 size recording paper **19**. The image density OD of solid black "bottom" shown in FIG. **15** is the image density of the trailing portion of the solid black image printed on the A4 size recording paper **19**.

As is clear from FIG. **15**, switching the voltage applied to the first supplying roller **7** from −300 V to −400 V shortly after printing has been performed on 10,000 pages can increase the image density for both the solid black "top" and solid black "bottom," if the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** is smaller than 0.9. It is also clear from FIG. **15** that if only the first supplying roller **7** is employed, the difference in image density between the solid black "top" and solid black "bottom" cannot be adjusted below OD=0.1 while maintaining the image density of the solid black "top" to OD=1.5.

Next, a test was conducted using both the first supplying roller **7** and second supplying roller **8**. The test results will be described in terms of the relationship among the ratios of the circumferential speeds of the first and second supplying rollers **7** and **8** to that of the developing roller **4**, the amount of toner deposited on the developing roller **4**, and the image density.

The developing roller **4** rotated at a circumferential speed of 156 mm/s. The first supplying roller **7** rotated at a circumferential speed of 109 mm/s. In other words, the ratio of the circumferential speed of the first supplying roller **7** to that of the developing roller **4** was set to 0.7. The ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** was varied from 0.1 to 1.2.

FIG. **16**A illustrates the relationship between the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** and the amount of toner deposited on the developing roller **4**.

FIG. **16**B illustrates the relationship between the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** and the image density.

The amount of toner deposited on the developing roller for developing the solid black "top" and solid black "bottom" are similar to those shown in FIG. **14** and their description is omitted. The image density for solid black "top" and solid black "bottom" are similar to those shown in FIG. **15** and their description is omitted.

As is clear from FIG. **16**A, switching the voltage applied to the first supplying roller **7** from −300 V to −400 V shortly after having printed on 10,000 pages of the recording paper **19** can increase the image density for both the solid black "top" and solid black "bottom". The amount of toner deposited on the developing roller **4** increases with decreasing ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4**, so that the difference in the amount of toner deposited on the developing roller **4** between the solid black "top" and solid black "bottom" decreases. This is because the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** is in a narrow range and is therefore subject to less wear. Thus, the second supplying roller **8** minimizes the decrease in the amount of scraped toner over time and the decrease in the amount of toner supplied to the developing roller **4**.

As is clear from FIG. **16**B, the image density increases with decreasing the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** for both the solid black "top" and solid black "bottom," if the voltage applied to the first supplying roller **7** is switched from −300 V to −400 V shortly after having printed on 10,000 pages of the recording paper **19** can increase. It is also clear from FIG. **16**B that if the ratio of the circumferential speed of the second supplying roller **8** to that of the developing roller **4** is in the range of 0.1 to 0.6, the difference in image density between the solid black "top" and solid black "bottom" can be below OD=0.1 while maintaining the image density for the solid black "top" to OD=1.5.

The fact that the difference in image density can be below OD=0.1 is considered due to the increase in the amount of residual toner **14***a* scraped by the second supplying roller **8**. The increase in the scraped amount of residual toner **14***a* results from the narrow range (i.e., 0.1 to 0.6) of the ratio of circumferential speed of the second supplying roller **8** to that of the developing roller **4**.

As described above, the image forming apparatus according to the second embodiment employs first and second supplying rollers for a single developing roller. The image bearing body, first supplying roller, and second supplying roller are disposed around the single developing roller in this order so that the image bearing body is upstream of the second supplying roller with respect to rotation of the developing roller, and the second supplying roller is upstream of the first supplying roller. The two supplying rollers are disposed side by side along the rotational direction of the single developing roller, and rotate at different ratios of the circumferential speed to that of the developing roller. The ratio of the circumferential speed of a second supplying roller upstream with respect to rotation of the developing roller is selected to be smaller than that for a first supplying roller downstream of the second supplying roller. This configuration provides sufficient supply of toner to the developing roller and is sufficiently effective in scraping the residual toner from the developing roller **4**, so that the difference or variation in image density within a page of the recording paper **19** can be minimized for high quality print image.

The first and second embodiments have been described with respect to a tandem image forming apparatus. The invention is not limited to a tandem image forming apparatus but may be applicable to an image forming apparatus having a monochrome image forming section, a four-cycle image forming apparatus with a single image bearing body, or a multi function peripheral such as a facsimile machine and a copying machine.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. An image forming apparatus comprising:

a developer bearing body that faces an image bearing body that bears an electrostatic latent image thereon, the developer bearing body supplying a developer material to the image bearing body to develop the electrostatic latent image;

a first supplying member that supplies the developer material to the developer bearing body; and

a second supplying member that is disposed upstream of the first supplying member with respect to a direction of rotation of the developer bearing body and supplies the developer material to the developer bearing body;

wherein a circumferential speed of the first supplying member is higher than a circumferential speed of the second supplying member;

wherein the first supplying member rotates in a direction in which the second supplying member rotates;

wherein the ratio of the circumferential speed of the first supplying member to a circumferential speed of the developer bearing body is larger than the ratio of the circumferential speed of the second supplying member to the circumferential speed of the developer bearing body; wherein the ratio of the circumferential speed of the second supplying member to the circumferential speed of the developing bearing body is equal to or smaller than 0.6.

2. The image forming apparatus according to claim **1**, wherein the first supplying member rotates in a direction in which the developer bearing body rotates.

3. The image forming apparatus according to claim **1**, wherein the second supplying member is in contact with the developer bearing body.

4. The image forming apparatus according to claim **1** further comprising:

a printing controller configured to perform overall control of the image forming apparatus;

a counter configured to count a cumulative number of printed pages;

a voltage applying section configured to apply a voltage to the first supplying member and a voltage to the second supplying member;

wherein the printing controller drives the voltage applying section to increase the voltages applied to the first supplying member and the second supplying member when the cumulative number of pages has reached a reference value.

5. The image forming apparatus according to claim **4**, wherein the printing controller changes the voltage applied to the first supplying member and the voltage applied to the second supplying member, while maintaining a difference between the voltage applied to the first supplying member and the voltage applied to the second supplying member.

6. The image forming apparatus according to claim **1**, wherein the ratio of a circumferential speed of the first supplying member to a circumferential speed of the developer bearing body is in a range of 0.7 to 1.3, and the ratio of the circumferential speed of the second supplying member to the circumferential speed of the developer bearing body is in a range of 0.1 to 0.6.

7. The image forming apparatus according to claim **1**, wherein the first supplying member is in contact with the developer bearing body.

8. An image forming apparatus comprising:

a developer bearing body that faces an image bearing body that bears an electrostatic latent image thereon, the developer bearing body supplying a developer material to the image bearing body to develop the electrostatic latent image;

a first supplying member that supplies the developer material to the developer bearing body; and

a second supplying member that is disposed upstream of the first supplying member with respect to a direction of rotation of the developer bearing body and supplies the developer material to the developer bearing body;

wherein a circumferential speed of the first supplying member is higher than a circumferential speed of the second supplying member;

wherein the first supplying member rotates in a direction in which the second supplying member rotates;

wherein the first supplying member is in contact with the developer bearing body; and wherein the developer bearing body and the first supplying member form a nip therebetween, the nip has a depth given as follows:

$$D=(r1+r2)-L \text{ 0.6 mmˆDˆ1.4 mm}$$

where D is the depth of the nip, r**1** is the radius of the developer bearing body, r**2** is the radius of the first supplying member, and L is the distance between the rotational axes of the first supplying member and the developer bearing body.

9. The image forming apparatus according to claim **8**, wherein the ratio of the circumferential speed of the first supplying member to the circumferential speed of the developer bearing body is equal to or greater than 0.7.

10. The image forming apparatus according to claim **8**, wherein the ratio of the circumferential speed of the first supplying member to the circumferential speed of the developer bearing body is larger than the ratio of the circumferential speed of the second supplying member to the circumferential speed of the developer bearing body.

11. The image forming apparatus according to claim **8**, wherein the ratio of the circumferential speed of the second supplying member to the circumferential speed of the second circumferential speed of the developing bearing body is equal to or smaller than 0.6.

12. The image forming apparatus according to claim **8**, wherein the first supplying member rotates in a direction in which the developer bearing body rotates.

13. The image forming apparatus according to claim **8**, wherein the second supplying member is in contact with the developer bearing body.

14. The image forming apparatus according to claim **8**, further comprising:

a printing controller configured to perform overall control of the image forming apparatus;

a counter configured to count a cumulative number of printed pages;

a voltage applying section configured to apply a voltage to the first supplying member and a voltage to the second supplying member;

wherein the printing controller drives the voltage applying section to increase the voltages applied to the first supplying member and the second supplying member when the cumulative number of pages has reached a reference value.

15. The image forming apparatus according to claim **14**, wherein the printing controller changes the voltage applied to the first supplying member and the voltage applied to the second supplying member, while maintaining a difference between the voltage applied to the first supplying member and the voltage applied to the second supplying member.

* * * * *